P145532.PDF [Page: 5 of 43]

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HIGH ARCTIC TRIALS OF A MAGELLAN 5000 PRO DIFFERENTIAL GLOBAL POSITIONING SYSTEM

by

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ABSTRACT

Differential Global Positioning System receivers were used to carry out location of local area survey control stations in the high Arctic in April, 1993. Two Magellan 5000 Pro handheld GPS receivers which utilize a carrier-phase technique for position measurement were used in conjunction with Magellan post-processing software to achieve the differential corrections. Range accuracies were compared to survey work carried out with conventional laser-ranging survey equipment with a mean agreement of 0.24 m between the two systems.

TABLE OF CONTENTS

	PAGE
ABSTRACT	iii
INTRODUCTION	1
DIFFERENTIAL GPS SURVEY EQUIPMENT	1
GPS SURVEY CONTROL STATION	4
PREPARATION FOR SURVEYING	4
SATELLITE SELECTION PLANNING	5
COMMUNICATIONS	7
PREPARATION OF FIELD EQUIPMENT	7
COLLECTING THE GPS POSITION DATA	8
POST-PROCESSING OF THE COLLECTED DATA SETS	9
INDEPENDENT MEASUREMENT OF DGPS POSITIONING	11
DGPS POSITION VARIABILITY	12
CONCLUSION	15
BIBLIOGRAPHY	15
APPENDIX A	A1
SPECIFICATIONS FOR MAGELLAN 5000 PRO RECEIVER	A2
APPENDIX B	B1
GPS SURVEY CONTROL STATION	B2
APPENDIX C	C1
DISCREPANCIES IN MAGELLAN 5000 PRO CALCULATIONS	C2

INTRODUCTION

As part of ICESHELF 93, an Arctic Ocean scientific program conducted by the Defence Research Establishment Pacific's Arctic Acoustics Group in the area off the northern shore of Ellesmere Island, NWT, a differential Global Positioning System (GPS) survey was carried out to tie together control stations used for local area surveys which were done with conventional survey techniques. A map of the general area of this work is shown in Figure 1. This report describes the equipment used for the differential GPS survey, discusses the establishment of a GPS survey master control station, and discusses the differential GPS survey position data obtained. Positions are reported as NAD 83 or WGS 84 UTM grid positions in Zone 20. Confirmation of the relative accuracy of the differential GPS positions of some of the remote survey control stations was obtained using conventional survey equipment.

DIFFERENTIAL GPS SURVEY EQUIPMENT

The differential GPS equipment used for this survey was based on Magellan 5000 Pro handheld GPS receivers. Specifications for these units are given in Appendix A. The differential GPS survey system consisted of two of the Magellan 5000 Pro receivers used in conjunction with Magellan multipath resistant antenna kits. Each receiver was connected to a data logging computer, a portable PC at the fixed master station, and an HP 95LX, palmtop computer for the mobile remote station. A photograph of this equipment is shown in Figure 2. The survey system achieves its precision by post-processing records of GPS position data collected simultaneously at two positions using the same four satellites. The Magellan post-processing software program, Version 2.6, was installed in the control station PC for planning, logging, and post-processing of the position data sets. A special data logging software package from Tripod Data Systems, Inc., specifically designed for use with the Magellan 5000 Pro, was used in the HP 95LX palmtop. Data were stored in 2 Mbyte SRAM PCMCIA cards in the HP 95LX and these data were transferred to the control station PC for analysis by removing the memory card from the palmtop and placing it in a PCMCIA RAM card drive on the PC. This method of data transfer was much faster than via serial port which is the only alternative on the HP 95LX palmtop.

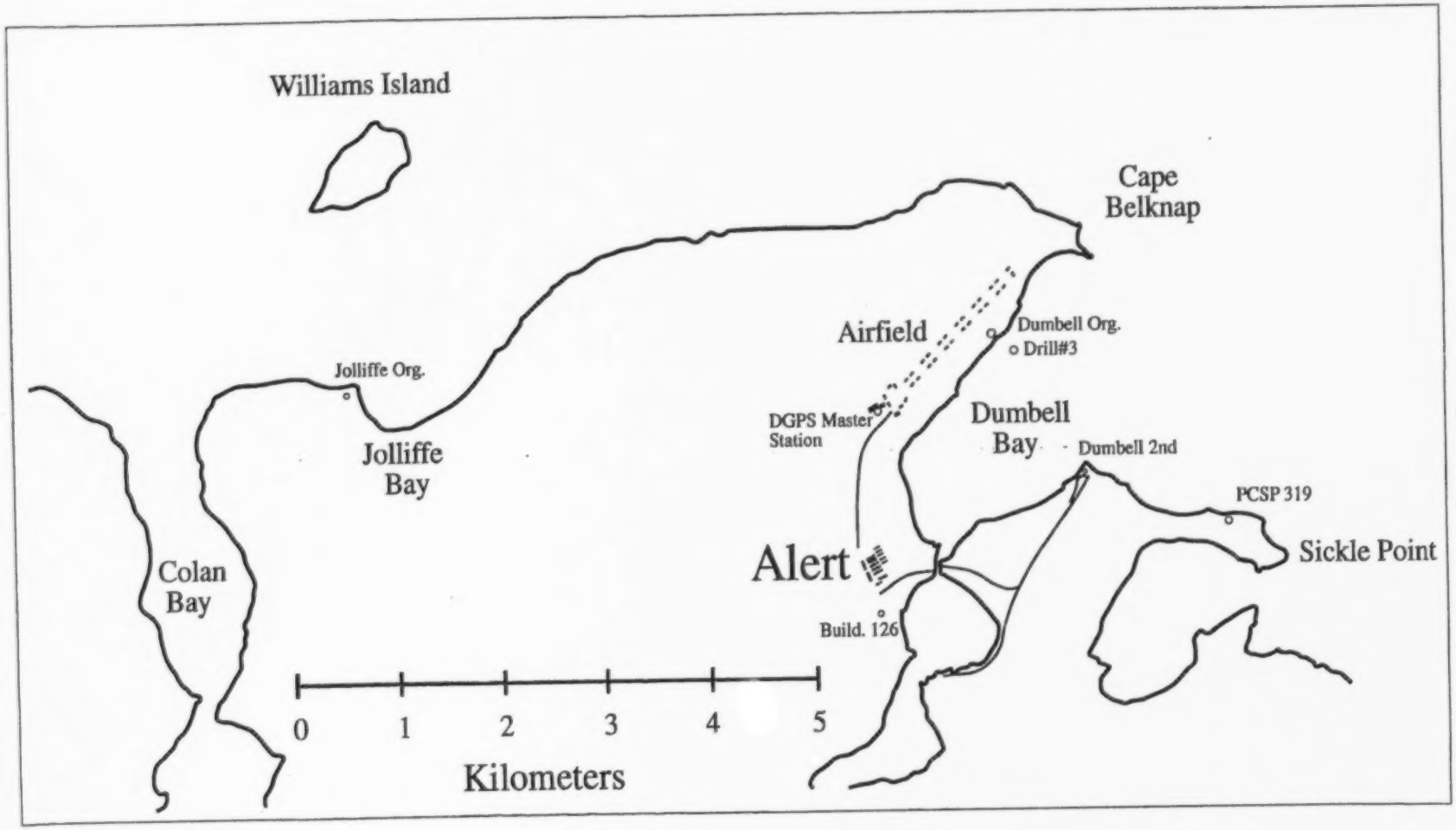

Figure 1: Operations Area for Iceshelf 93.

A carrier-phase position measurement technique is used by the Magellan 5000 Pro receivers.[1,2] The cycle slip range ambiguity problem associated with this technique is resolved in these units by measurement of the doppler shifts of the carriers of the four satellites being used. Each Magellan 5000 Pro unit then determines the latitude, longitude, and altitude at which computed doppler shifts based on previously stored satellite ephemeris data agree with the values observed. This equipment is relatively inexpensive compared to centimeter accuracy GPS survey systems and provided a good compromise for the type of survey that was being carried out. Total cost of the system excluding the PC was about $10,000. The small size and portability of the mobile station equipment allowed the GPS receiver and the palmtop logging computer to be carried in inside parka pockets where they could be kept warm.

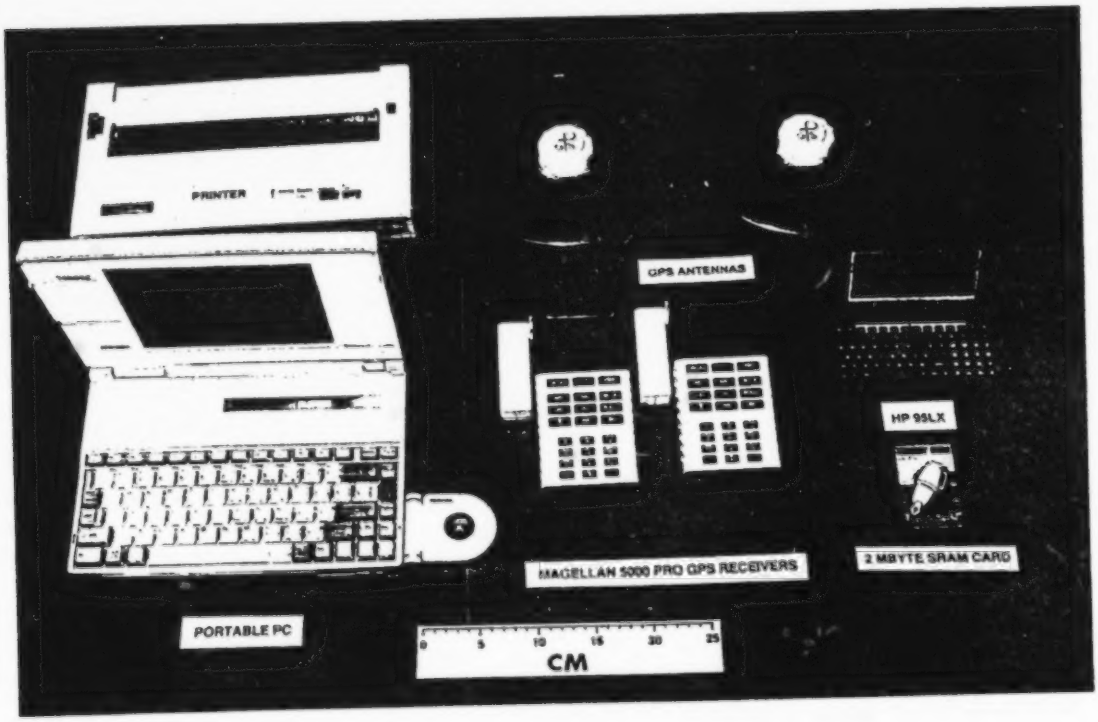

Figure 2: Photograph of the Differential GPS Measurement Equipment.

GPS SURVEY CONTROL STATION

Initially no survey control stations from previous surveys were available so a master control station was established by carrying out long-term averaging of GPS positions taken with a single receiver at the fixed control station antenna site. A discussion of this procedure in given in Appendix B. During the survey, the position of an old survey pin, PCSP 319, from a previous geodedic survey was measured. The position information for this pin was obtained from the Geodetic Survey of Canada so it was decided to use the GSC position of this pin as the control reference. The position of the master station was adjusted so that all positions obtained with this survey would be referenced to and agree with survey control stations on existing maps of the area made using information from the previous survey work.

PREPARATION FOR SURVEYING

Prior to going in the field for a day's surveying, a number of procedures were carried out to prepare for the survey work. The first step was to collect a current almanac on each of the 5000 Pro GPS units. These units read the internally stored almanac each time they are turned on to determine the satellite constellation visible at that time. Having a current almanac minimizes the search time for visible satellites each time the units are turned on which can be several minutes. Once a current almanac was stored and verified in the control station 5000 Pro unit, this almanac was down loaded to the control station PC. This almanac is used in the planning part of the Magellan PC software program.

SATELLITE SELECTION PLANNING

With a current almanac stored in the PC, the Plan part of the Magellan software program was started. Input parameters for the Plan program are; almanac file name, latitude, longitude, planning date, minimum or mask angle above the horizon for acceptance of satellite signals as low angle signals can cause significant errors due to multipath and atmospheric propagation effects (set at 15°), interval for calculation of optimum satellite constellation (set at 20 minutes), and offset from UTC to local time in hours. With these parameters set the program produced output displays which could be printed. The carrier phase mode display was most relevant for this survey. It consists of a display of the optimum satellite constellations for each time interval with an associated quality factor called CPDOP which is an acronym for Carrier Phase Dilution of Precision. This quality factor considers the best satellite configuration for the doppler assisted carrier phase mode of operation used in the Magellan 5000 Pro receivers. Since carrier doppler shift is a function of satellite velocity relative to the observer, satellite velocities are incorporated in the CPDOP geometric figure of merit. Lower numbers provide better positioning accuracy and values of 40 and below were considered acceptable. Convergence of the GPS satellite orbits over the North Pole provides better satellite visibility at high latitudes than at latitudes closer to the equator. During this survey, at latitude 82° N, CPDOP values less than 25 were observed most of the time and were significantly better than those observed at latitude 48° N. A sample of the Carrier Phase Plan Table is given in Table 1.

Table 1: Example of the Output From the Carrier Phase Planning Program.

CPDOPs for 04/27/93 Local offset from UTC -4:00
LATITUDE +82 30 40.500 LONGITUDE - 62 19 37.250 Mask angle 15 degrees

Time hh:mm	CPDOP (sats)	Based on 10 min. session beginning at time indicated		
00:00	18.7(3,16,22,24)	21.0(16,18,22,24)	22.5(3,16,22,29)	22.9(16,22,24,29)
00:20	19.4(3,16,22,24)	21.3(3,19,22,24)	22.8(16,18,22,24)	24.5(18,19,22,24)
00:40	18.8(3,17,22,24)	20.0(3,16,17,22)	20.5(16,17,19,24)	20.8(3,17,18,22)
01:00	19.4(16,17,19,24)	19.5(3,16,17,22)	19.6(3,17,22,24)	20.6(16,17,19,22)
01:20	18.7(16,17,22,27)	19.1(16,17,19,22)	19.5(3,16,17,19)	20.6(3,16,17,22)
01:40	17.4(16,17,22,27)	19.1(16,17,19,22)	20.0(3,16,22,28)	20.0(3,16,17,19)
02:00	18.0(16,17,22,27)	18.7(16,17,22,26)	20.7(16,17,19,22)	21.0(3,16,17,27)
02:20	20.5(17,19,26,28)	20.6(16,19,26,28)	20.9(16,17,26,28)	21.2(3,17,26,28)
02:40	19.4(3,17,26,28)	19.6(17,19,26,28)	20.2(16,17,26,28)	20.8(3,17,27,28)
03:00	18.0(17,19,23,28)	18.4(17,23,27,28)	19.8(17,19,26,31)	20.3(17,19,26,28)
03:20	18.0(17,23,27,28)	18.7(17,19,23,28)	19.8(17,23,27,31)	20.2(17,19,26,31)
03:40	18.6(17,21,27,28)	18.6(17,23,27,31)	18.7(2,23,27,28)	19.0(17,23,27,28)
04:00	18.0(2,21,26,28)	19.3(17,23,27,31)	19.7(2,23,27,28)	20.0(17,21,27,31)
04:20	18.3(2,21,26,28)	20.3(2,21,27,31)	20.8(2,23,27,31)	21.0(2,17,21,31)
04:40	20.4(2,21,26,28)	21.0(2,21,26,31)	24.5(2,23,26,28)	25.8(23,26,28,31)
05:00	20.4(2,15,26,31)	21.0(2,15,23,31)	22.1(2,21,26,31)	24.2(2,15,21,31)
05:20	21.0(2,15,23,31)	21.2(2,15,26,31)	21.3(12,21,26,31)	21.9(2,12,15,26)
05:40	18.6(1, 2,15,23)	19.0(1, 2,15,21)	19.4(2,12,15,23)	20.0(2,12,15,21)
06:00	18.4(1, 2,15,21)	18.5(2,12,15,21)	18.5(2,12,15,23)	18.7(1,12,15,23)
06:20	17.9(1,12,15,23)	18.5(2,12,15,21)	19.3(1, 2,15,21)	19.4(1,12,15,21)
06:40	18.9(1,12,15,23)	19.6(1, 2, 5,15)	19.7(1,12,15,21)	20.1(2,12,15,21)
07:00	21.6(1, 7,12,21)	21.8(1,12,15,21)	25.1(1, 5,15,21)	27.2(1, 7,15,21)
07:20	23.2(1, 7,12,21)	25.9(1, 5,15,21)	26.6(1,12,15,21)	27.2(1, 5,12,15)
07:40	17.5(1, 5,14,15)	18.1(7,12,14,15)	18.3(1,12,14,15)	19.4(1,12,15,20)
08:00	17.2(1, 5,14,15)	19.3(7,12,14,15)	20.1(1, 7,14,20)	20.2(1,14,15,20)
08:20	18.2(1, 7,14,25)	18.5(1, 7,14,20)	20.6(7,12,14,20)	20.7(1, 5,14,25)
08:40	18.1(1, 7,14,25)	18.7(1, 7,14,20)	19.9(1, 5,14,25)	21.7(7,12,14,20)
09:00	20.9(1, 5,14,25)	23.5(1,14,20,25)	23.6(12,14,20,25)	25.4(1, 5,14,29)
09:20	23.3(1,14,20,25)	24.1(1, 5,14,25)	26.9(1, 5,14,29)	26.9(1,20,25,29)
09:40	19.3(5,14,24,25)	21.8(14,20,24,29)	22.0(14,24,25,29)	22.3(5,14,24,29)
10:00	19.7(14,20,24,29)	20.2(14,24,25,29)	29.8(14,20,24,25)	34.2(14,20,25,29)
10:20	19.1(14,20,24,29)	19.7(14,24,25,29)	20.3(22,24,25,29)	20.3(20,22,24,29)
10:40	18.2(20,22,24,29)	19.4(18,22,24,25)	20.1(14,20,24,29)	20.3(14,18,24,25)
11:00	17.7(20,22,24,29)	18.2(18,22,24,25)	19.3(18,22,24,29)	19.6(14,18,22,24)
11:20	18.6(18,22,24,25)	18.7(18,22,24,29)	18.8(20,22,24,29)	20.1(3,18,20,22)
11:40	18.7(16,22,24,29)	19.4(18,22,24,29)	19.8(16,18,22,24)	20.7(18,22,24,25)
12:00	19.2(16,18,22,24)	20.5(16,22,24,29)	21.5(18,22,24,29)	21.7(3,16,22,24)
12:20	19.6(16,18,19,22)	20.0(16,18,22,24)	20.3(3,16,19,29)	20.3(3,18,19,22)
12:40	18.9(16,18,19,22)	19.7(17,18,19,22)	21.1(17,18,22,24)	21.1(3,18,19,22)
13:00	19.6(16,18,19,22)	19.7(17,18,19,22)	20.2(16,19,22,28)	20.4(3,16,18,19)

COMMUNICATIONS

The carrier phase mode of differential GPS surveying used by the Magellan equipment requires that the receivers at the control and remote stations be locked onto the same set of four satellites and that data be logged for about 10 minutes simultaneously at both sites. Coordination of this logging effort requires considerable communication between the two sites so a good communications system is imperative. VHF handheld transceivers with proven service at cold temperatures were used with good success. Direct point-to-point operation was used where line-of-conditions existed and a half-duplex VHF repeater on a mountain peak was used for larger area coverage.

PREPARATION OF FIELD EQUIPMENT

Since this survey work was performed in Arctic spring conditions with temperatures ranging from - 20°C to - 30°C, an effort was made to minimize the number of operations and the time required to collect the remote station GPS data samples. The GPS antenna has an internal rechargeable battery pack so its state of charge had to be ensured each day. The 5000 Pro GPS receiver and the HP 95LX computer have primary batteries so spare packs were carried at all times. Spare battery packs for the VHF portable transceiver were also carried. The data logging files in the HP 95LX could be initialized so that the only field operations required were to turn the power on and start logging data.

COLLECTING THE GPS POSITION DATA

All remote stations surveyed were reached by truck if they were on graded roads and by Skidoo otherwise. Upon arrival at the site, the GPS antenna was mounted on a tripod over the survey point or iron pin and connected to the Magellan 5000 Pro receiver. The receiver was connected to the HP 95LX computer for data logging. Upon turn on and access of the Carrier Phase mode of operation, the 5000 Pro takes 2 to 3 minutes to determine the optimum satellite configuration for this mode of operation at that time. The set of satellites is displayed and there is opportunity to change them if they do not agree with the printout from the Plan session done previously. Communication took place with the control station operator via VHF radio to ensure that both stations were ready to begin coordinated logging with the same set of four satellites. The goal was to have coordinated data logging for 10 minutes for each data set. This was not always realized due to satellite signal drop outs or coordination mix-ups. The impact of shorter data logging sessions will be discussed later.

Through experience it was learned that it was important to keep the HP 95LX warm in an inside parka pocket. A few minutes of exposure to the ambient temperatures, which were -20 °C to -25 °C, would cause the display to dim and the computer to lock-up. The Magellan 5000 Pro was less susceptible to the cold but every effort was made to keep it as warm as possible inside the parka. No malfunctions of the 5000 Pro or the active GPS antenna due to cold temperature were experienced.

POST-PROCESSING OF THE COLLECTED DATA SETS

The data log in the HP95LX palmtop computer was stored on 2 Mbyte PCMCIA SRAM cards which have internal battery back-up so they do not lose data while they are out of the computer. The data was transferred to the control station computer for post-processing by placing the SRAM card in a PCMCIA card drive and doing file transfers to the system's hard disk drive. Each data file contained 350 to 450 kilobytes of data so this method of data transfer was much faster than any other means available. The Magellan carrier phase post-processing was then started and the appropriate data files for control and remote sites were selected. With all parameters set, the program would take about five minutes to process a single data set on a 10 MHz 286/287 PC. A sample of the output from this program is given in Table 2.

Table 2: An Example of the Output From the Carrier Phase Post-processing Program

```
                DOUBLE-DIFFERENCED CARRIER PHASE 3D SOLUTION SUMMARY

CONTROL POSITION                      SESSION INFORMATION
   NORTHING : N 091-61-951.85            Sats used :    17 23 27 28
   EASTING  : 20  5-09-785.38            Carrier Measurements : 448
   ELLIP. HT. :   36.72 M                CPDOP for session  :  23.9
                                         Start and Stop Time : 11:10 -> 11:18
   EPHEMERIS FILE : TEST10.DAT           Duration of session :  7 min  46 sec
   CONTROL FILE   : TEST10.DAT
   REMOTE FILE    : POST319.GPS                      CORRECTIONS    BASELINE
                                         North  (Y) :    64.94 M       -1163.00 M
CORRECTED REMOTE LOCATION                East   (X) :    6.09 M        3498.20 M
   NORTHING : N 091-60-837.38            Height (Z) :    -402.2 M      -23.06 M
   EASTING  : 20  5-13-297.79            Length (2D):                  3686.46 M
   ELLIP. HT. :   13.66 M                Length (3D):                  3686.53 M
DATA SETS COLLECTED
```

The sets of GPS data collected are summarized in Table 3.

Table 3: Differential GPS Survey Data.

LOCATION	DATE M/D/Y	TIME UTC	DURATION MIN:SEC	NO. OF MEAS.	CPDOP	LATITUDE (° ' " N)	LONGITUDE (° ' " W)	ELEV. (m)	UTM GRID NORTHING	UTM GRID EASTING
Build. 126	4/26/93	23:09	9:41	558	18.4	82 29 41.384	62 20 22.649	60.61	91-60-121.12	5-09-629.59
Build. 126	4/27/93	13:37	8:36	493	20.9	82 29 41.392	62 20 22.693	60.64	91-60-121.37	5-09-629.41
Build. 126	4/27/93	13:51	9:11	535	20.0	82 29 41.391	62 20 22.661	60.62	91-60-121.34	5-09-629.54
Pump Hs. Rd.1	4/27/93	15:26	9:32	548	18.7	82 29 07.532	62 27 50.354	25.67	91-59-052.70	5-07-825.93
Pump Hs. Rd.2	4/27/93	16:29	9:53	570	17.7	82 29 43.743	62 23 39.771	66.14	91-60-185.51	5-08-830.40
Pump Hs. Rd.3	4/27/93	16:54	5:59	345	32.3	82 29 36.769	62 21 01.889	59.73	91-59-976.22	5-09-472.22
Dumbell Org.	4/29/93	14:55	6:12	358	30.2	82 31 03.400	62 14 57.057	11.87	91-62-680.21	5-10-915.43
Dumbell Org.	5/1/93	15:06	8:40	500	22.6	82 31 03.401	62 14 57.054	12.07	91-62-680.23	5-10-915.32
Dumbell Org.	5/1/93	15:17	9:51	569	21.4	82 31 03.390	62 14 57.051	12.35	91-62-679.89	5-10-915.34
Drill#3	5/1/93	15:48	10:3	580	31.0	82 31 01.940	62 14 04.170	0.60	91-62-637.74	5-11-129.47
Dumbell 2nd	4/29/93	18:22	8:52	511	20.2	82 30 18.220	62 11 16.843	25.74	91-61-291.41	5-11-824.23
Dumbell 2nd	5/1/93	18:29	9:57	574	18.8	82 30 18.212	62 11 16.718	26.76	91-61-291.17	5-11-824.74
Dumbell 2nd	5/1/93	18:46	7:07	412	25.8	82 30 18.226	62 11 16.887	26.48	91-61-291.57	5-11-824.05
PCSP 319	4/29/93	19:10	7:46	448	23.9	82 30 02.870	62 05 14.401	13.21	91-60-837.35	5-13-297.72
PCSP 319	5/1/93	19:09	11:32	663	16.6	82 30 02.877	62 05 14.215	14.86	91-60-837.58	5-13-298.47
Jolliffe Org.	4/29/93	21:03	7:17	420	25.9	82 30 49.667	62 41 10.815	14.24	91-62-195.82	5-04-562.41

INDEPENDENT MEASUREMENT OF DGPS POSITIONING

Since local area surveys were being carried out using conventional laser ranging survey equipment it was possible to make independent measurements of the ranges and bearings between some of the remote stations surveyed with the Magellan DGPS equipment. The instrument used for the conventional survey was a Geodometer Model 140 laser ranging survey instrument. Range accuracy of this instrument is specified as ± 10 mm over a 1 km range or ± 0.001%. It was possible to compare data from three sets of measurements. Since multiple sets of DGPS position data were obtained for some of the sites, these data were averaged for comparison with the Geodometer data. These data sets are compared in Table 4.

Table 4: Comparison of Geodometer and Magellan DGPS Survey Data.

FROM STATION	TO STATION	GEOD. RANGE (m)	GEOD. BEARING (° ')	DGPS RANGE (m)	DGPS BEARING (° ')	RANGE DIFF. (m)	BEARING DIFF. (')
Dumbell Org.	Dumbell 2nd	1660.47	147 34.4	1660.42	147 32.3	-0.05	-2.1
Dumbell 2nd	PCSP 319	1542.93	107 53.2	1542.68	107 55.4	-0.25	+2.2
Dumbell Org.	Drill#3	218.78	101 54.0	218.35	101 56.3	-0.43	+2.3

The comparison given in Table 4 shows that the Magellan DGPS system performed well within its 0.9 m accuracy specification for relative positioning with a mean difference between the two survey systems of 0.24 m over the three position measurements. The impact of averaging multiple measurements is also shown as the positions for Dumbell Org. and Dumbell 2nd are the average of three DGPS measurements each, the PCSP 319 position is the average of two DGPS measurements and that of Drill#3 is only a single measurement. Agreement with the Geodometer measurements varies directly with the number of DGPS position measurements taken and averaged.

DGPS POSITIONING VARIABILITY

In an attempt to determine the variability of the DGPS positions, repeat measurements were taken at a number of the survey points. Three stations, Building 126, Dumbell Org. and Dumbell 2nd, had three measurements taken at each of them. Some of the repeat measurements were taken one or two days apart so different satellite constellations were used. Times of the measurements are given in Table 3. Scatter plots for the three positions are given in Figures 3, 4 and 5. A mean position, determined by averaging the Northings and Eastings separately, is shown on each plot. The number of individual measurements used to determine each position is also shown, in an attempt to see if there is any relation between the length of the logging session and the agreement of position measurements.

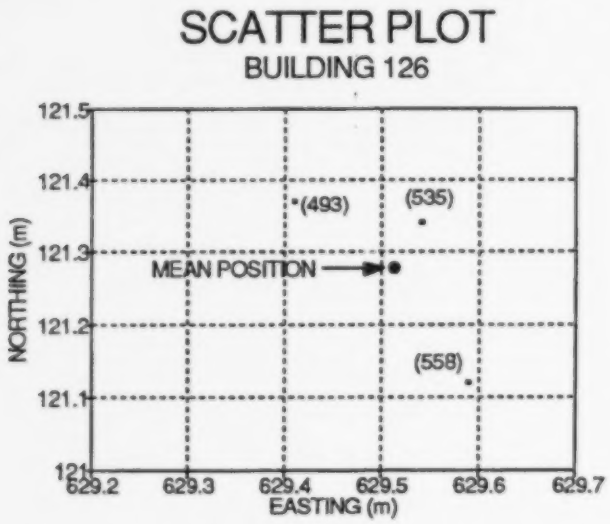

Figure 3: Scatter Plot of Repeat Position Measurements Taken at Building 126 Station. Northings and Eastings are shown as offsets from UTM Grid Position 91-60-000 m North, 5-09-000 m East, Zone 20.

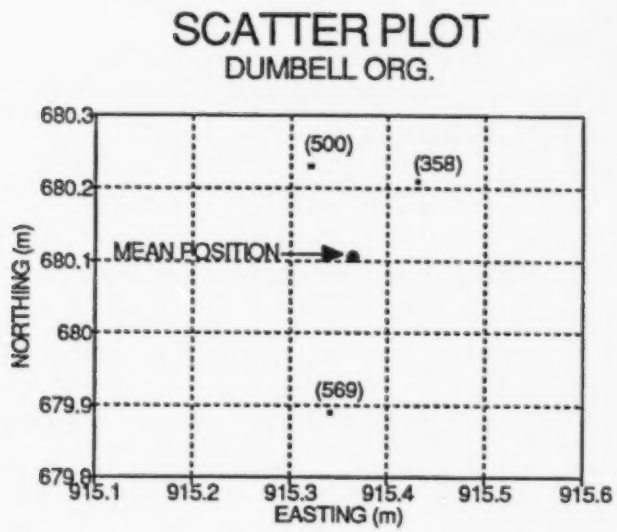

Figure 4: Scatter Plot of Repeat Position Measurements Taken at Dumbell Org. Station. Northings and Eastings are shown as offsets from UTM Grid Position 91-62-000 m North, 5-10-000 m East, Zone 20.

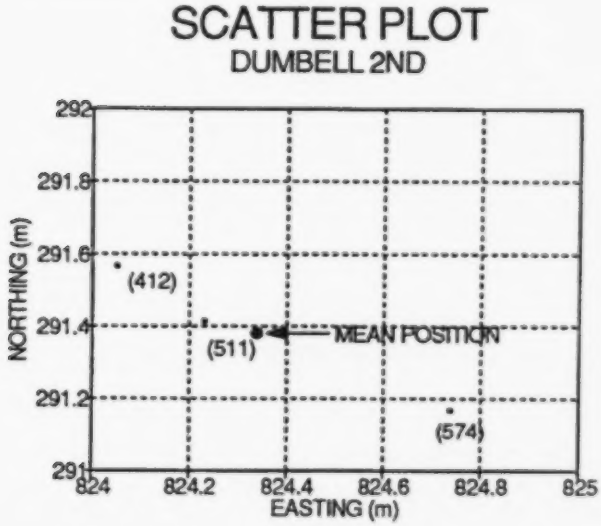

Figure 5: Scatter Plot of Repeat Position Measurements Taken at Dumbell 2nd Station. Northings and Eastings are shown as offsets from UTM Grid Position 91-61-000 m North, 5-11-000 m East, Zone 20.

If a position is known, error vectors e_i can be drawn from the known position to estimates p_i of that position. In two dimensions, e_i has components x_i and y_i which are the Easting and Northing differences respectively between p_i and the known position. The RMS error of the position estimates, p_i, is defined in Equation 1.[3]

$$\text{RMS error (in 2D)} = \sqrt{\frac{1}{N} \sum_{i=1}^{N} (x_i^2 + y_i^2)} \qquad (1)$$

If the error vectors have a zero mean, circular normal distribution, then 63% of the fixes will fall in a circle having a radius equal to the RMS error, and 98% will fall in a circle of radius twice this value. Using the mean position as the correct position, the RMS error was calculated for the three stations shown in Figures 3, 4 and 5. These values are given in Table 5.

Table 5: RMS Error Calculations for DGPS Measurements.

STATION	RMS ERROR (m)
Building 126	0.13
Dumbell Org.	0.16
Dumbell 2nd	0.34

CONCLUSION

Magellan 5000 Pro handheld GPS receivers were used to carry out survey work in the high Arctic using a post-processing differential correction technique. Comparison of survey accuracies using the differential GPS equipment and conventional laser-ranging survey equipment provided agreement within a mean value of 0.24 m or 0.07 % of range over three cases. Agreement for individual cases improved with the number of data sets taken at particular sites. RMS error calculations were carried out for sites where repeat measurements were made. The mean RMS error was 0.21 m for three sites and a total of ten separate data sets. The mean RMS error for a single site decreased as the number of data sets taken at that site increased.

Disadvantages of using the Magellan DGPS system are the requirement for coordinated voice communications and data logging and the requirement to have a data logging computer at the remote site operating under ambient temperature conditions. Shorter logging periods would make the system more usable and the trade off in measurement accuracy verses length of the logging time period needs to be investigated.

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2. Vogel, W. M. & Lachapelle, G., "Differential GPS Methods and Performance for Marine Applications", DREP Contractors Report 93-09, January, 1993.

3. "Magellan GPS Post-Processing Software User Guide", Magellan Systems Corporation, San Dimas, Ca., 1992.

APPENDIX A

SPECIFICATIONS FOR MAGELLAN 5000 PRO GPS RECEIVER

PHYSICAL CHARACTERISTICS:

Unit Size:	3.5" x 8.75" x 2.13" (excluding antenna); (8.89 cm x 22.23 cm x 5.41 cm) 5.0" x 9.0" x 2.5" (bracket-mounted) (12.70 cm x 22.86 cm x 6.35 cm)
Weight:	30 ounces (0.85 kg) with batteries
Display:	4 line, 16 character, alphanumeric, backlit LCD
LCD Dimension:	2.56" x 1.77" (6.5 cm x 4.5 cm) 0.28' (0.71 cm) high digits (w/cursor)
LCD Operating Temperature:	-10°C to +60°C
Case:	Waterproof (Battery compartment is splashproof.)
Buoyancy:	Specific Gravity compared to water = 0.8 (it floats)
Safe Storage Temperature:	-40°C to +70°C
GPS Exterior Antenna:	3.5" (8.89 cm) diameter x 3.5" (8.89 cm) height with a 5/8-11 adapter, plus 13.12 feet (4 meters) of cable. (Part of Exterior Antenna Kit.)
GPS Multi-Path Resistant Antenna:	9.0" (22.86 cm) diameter x 2.09" (5.31 cm) height, plus 13.12 feet (4 meters) of cable. (Part of Submeter Kit.)

DATA CHARACTERISTICS:

Accuracy:	Position: 12 meters RMS (horizontal) with a single unit, in the absence of SA; 3 meters RMS (horizontal) with post-processed differential; 0.9 meters RMS (horizontal) with carrier phase. Velocity: 0.19 km/hr (HDOP <2, C/N_0 ≥47 dB-Hz, 2D)
Velocity:	0 to 1530.5 km/hr (O to 951 mph)
Time to First Fix:	55 seconds typical (cold start) 35 seconds typical (warm start)
Update Rate:	1 second typical, using POS with the dataport off
Memory:	500 user-stored waypoints, initial position, and up to 1500 of the previous fixes.
Modes of Operation:	2D (solves for position and time with a user-entered altitude using best three satellites), or 3D (solves for position, altitude, and time using best four satellites), or Automatic (uses 2D or 3D, depending on number of available satellites with good geometries).

ELECTRICAL CHARACTERISTICS:

Power Requirements:	Six AA alkaline batteries (internal) or six internal NiCad batteries, 10 to 15 volts DC with adapter 115 volts AC ±10%, with adapter
Battery Consumption:	160 mA without backlight on display 185 mA with backlight on display

APPENDIX B

GPS SURVEY CONTROL STATION

Initially no survey control stations from previous surveys were available for this survey so the master control station was established by carrying out long-term averaging of GPS positions with a single receiver at the fixed control station antenna site. Sixteen sets of measurements, each made by averaging 300 or 500 position measurements were taken periodically over a period of three days. These data sets, which were derived from 6200 position measurements, were plotted and a mean position was selected as the control station position. A plot of the 16 data sets and the selected control station is shown in Figure B-1.

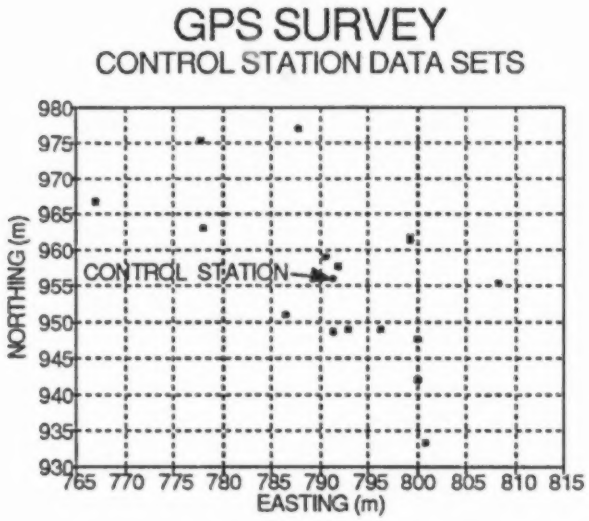

Figure B-1: Plot of Control Station Data Sets and Selected Survey Control Station. Northings and Eastings are shown as offsets from UTM Grid Position 091-61-000 m North, 5-09-000 m East, Zone 20.

A running average was applied to the 16 data sets to determine the rate of convergence to the final control station position. A plot of this running average is shown in Figure B-2. From this plot it can be seen that the average of the first three data sets brings the position within 1.5 m of the final position and the maximum excursion of any of the averaged sets following this is 2.8 m from the end point.

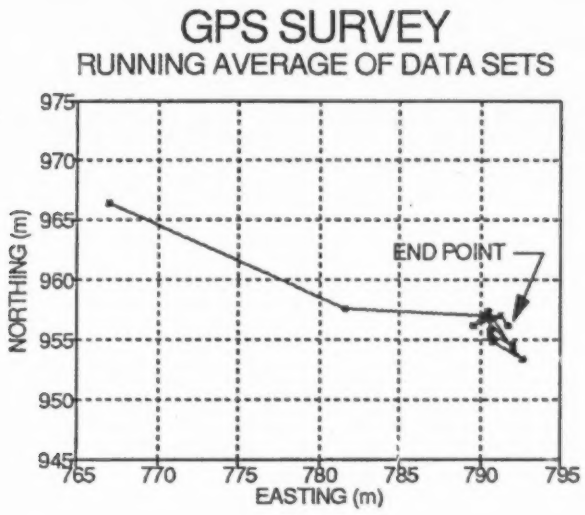

Figure B-1: Plot of a Running Average of the Control Station Data Sets. Northings and Eastings are shown as offsets from UTM Grid Position 091-61-000 m North, 5-09-000 m East, Zone 20.

Elevation at the master control station GPS antenna was initially set at 33 m based on CFS Alert runway survey data. This value was refined with the differential GPS survey system by collecting a differential data set for a location on the sea ice in Dumbell Bay. This data set provided a correction of +2.67 m so the control station GPS antenna elevation was set at 35.67 m above sea level. Using the Geodetic Survey of Canada information for PCSP Pin 319 as reference the correct elevation for the master control station antenna is 36.4 m.

APPENDIX C

DISCREPANCIES IN MAGELLAN 5000 PRO CALCULATIONS

Through the course of the work described in this report a discrepancy was found in one of the calculation modes of the Magellan 5000 Pro unit. The problem arose from use of the difference function, DIF 2, on the 5000 Pro units (Serial Nos. 3A00763 and 3A00808) to obtain the X and Y offsets between two positions stored as waypoints. At latitude 82° 30' North, both units give the same values but they are 0.3 % less than the correct values obtained by converting the lat/long positions to UTM grid and manually calculating the differences from the grid values. Switching the units from lat/long to UTM grid mode provided the same result. These errors seems to increase with latitude but this has not been fully investigated. It appears that users of 5000 Pros should be cautioned about using the DIF 2 function to calculate ranges between waypoint positions. The ROUTE function was also tried and gave point to point range values which did not agree exactly with the DIF 2 values or the correct values. The post-processing software 2D ranges agreed exactly with the UTM grid calculations provided the UTM scale factor correction in the region of the end point positions was used.

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Differential Global Positioning System receivers were used to carry out location of local area survey control stations in the high Arctic in April, 1993. Two Magellan 5000 Pro handheld GPS receivers which utilize a carrier-phase technique for position measurement were used in conjunction with Magellan post-processing software to achieve the differential corrections. Range accuracies were compared to survey work carried out with conventional laser-ranging survey equipment with a mean agreement of 0.24 m between the two systems.

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